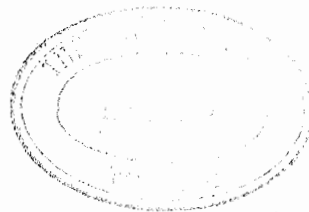


THE DEMAND FOR PUBLIC TRANSPORT IN HOBART



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PREFACE

This dissertation is an attempt to provide a causal explanation for the changes in demand for public transport in Hobart which have occurred during the past two decades, with the use of an econometric model.

In Chapter 1 the need for a reappraisal of existing and future plans for road construction in the city areas is examined, followed by a brief discussion of the ways in which the results obtained from this study may be found useful.

The second chapter is concerned with a review of three models of the demand for public transport which have been proposed by Australian and overseas authors. Each model considered was an extension of the traditional consumer demand theory, with demand depending on price and income; however certain other behavioural hypotheses are included in each of these models and their contributions are assessed. After a brief discussion of the structure and problems of the public transport industry in Chapter 3, a simultaneous equation model was formulated for the demand for intra-city passenger travel by rail, bus and ferry, as well as the demand for cars. To complete the model, an equilibrium relation was postulated linking the demand for passenger travel by these four modes.

Chapter 4 gives a brief outline of the many sources of data used in the estimation of the model. Published and unpublished information were made available by officers of the Transport Commission, Metropolitan Transport Trust, Public Works Department and the Hobart

City Council; supplemented by published data provided by the Commonwealth Bureau of Census and Statistics. The most serious limitation in the data was considered to be the lack of annual information on private vehicle trips made within the Urban Hobart Area.

Chapter 5 contains the results found from the estimation of the structural equations derived in Chapter 3. Using the time series data discussed in Chapter 4, various combinations of the variables were estimated by single equation least squares initially, and finally by two stage least squares. Each regression was assessed according to the significance and (correct) sign of the coefficients, the significance of the F statistic, and the value for  $\bar{R}^2$  and the Durbin-Watson Statistic. Personal income, the income distribution, television ownership and the service provided by public transport were found to be generally significant.

Further, a model consisting of the demand for travel by bus and rail, the demand for cars, and the total travel demand was solved to obtain the 'reduced form'. From these equations, the values 'predicted' by the model for bus and rail demand were obtained for the period 1955/56 to 1969/70 and compared with the actual demand in those years. In general, it was found that the comparative static multi-mode model did provide an adequate explanation of the demand for public transport in Hobart.

Forecasts of the level of bus and rail demand in 1974/75 were made assuming that these behavioural relationships would remain valid in the future, and that the

exogeneous variables would continue to follow the same trend as they have in the past. On the basis of various policies which may be available to the transport authorities forecasts were made for the level of rail and bus demand in 1974/75 consequent on the implementation of such policies.

These forecasts indicated that both the per capita and absolute level of demand for public transport is likely to continue to decline in the future, unless strong 'corrective' measures are taken to restrain the usage of private vehicles in the city areas, and to greatly increase the supply of public transport.

## CHAPTER ONE

### STATEMENT OF THE PROBLEM

In a recent transportation study of the Urban Hobart area, recommendations were made that at least \$62 million dollars (in 1970 prices) of state and local government money would be required to be spent on new highway and road systems (excluding bridges and parking facilities) during the period 1974 to 1990 to cater for the expected future traffic demands.<sup>1</sup> Such a rate of expenditure is almost three times as great as has been spent on new roads in the Urban Hobart area over the past 10 years (also in 1970 prices). The land required for these new road works and associated off-street parking facilities in the city areas would require the destruction of much valuable real estate, historic buildings and public recreation facilities; a cost the community is loathe to accept. Further, such finance as is made available for road works,<sup>2</sup> may well be at the expense of, or result in considerable delays in the implementation of other socially desirable projects.

The modernization of, and additions to the public transport system is one alternative to road construction which has received wide-spread public acclaim, though little research attention in Australia. Attempts have been made to increase the attractiveness of public transport by such ad-hoc measures as cheaper fares, more

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1. P.G. Pak Poy and Associates, Hobart Transportation Revision (Hobart, 1970). (Subsequently referred to as HTR Report) pp.29-42.
  2. An officer of the Southern Metropolitan Master Planning Authority, in a recent conversation, considered it most unlikely that finance would be made available for all those road works considered necessary in the HTR Report.

services, time-table and service route changes. These changes have usually been made without a full realization of what the intra-city commuters want from public transport, and hence whether the changes will satisfy the commuters sufficiently to induce them away from car travel. If expenditure on improvements to the public transport system is to be made as an alternative for additional expenditure on road construction in Hobart, then the trend in the absolute numbers, and relative share of commuters travelling by public transport,<sup>3</sup> will need to be reversed.

The object of this dissertation was to identify those causal factors which have in the past been responsible for the trend towards an increasing reliance placed on private automobile transportation and the decreasing use of public transport.

To do this, a model of public transport travel demand was formulated which included certain ideas contained in some of the travel demand models reported in the literature, as well as hypotheses considered relevant in explaining the demand for each travel mode (bus, rail, ferry, car). Alternative forms of the model were estimated using time series data both by single equation least squares (SELS) for each equation in the model, and by two stage least squares for the model as a whole. By solving the model to obtain the reduced form, it was possible to make predictions of both the travel demand for each mode and the effects of certain policy changes.

Information on the travel characteristics of city commuters was considered useful for three reasons.

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3. See graph at end of chapter 1.

Firstly, it would enable the identification of those factors and the extent of their influence which have caused the decline in public transport patronage. Increased fares, reduced service, and more competition from other travel modes have often been cited, however their relative influence is usually unknown. Secondly, the forecasts may help to provide a basis for any proposed alterations to the service and long run investment plans of both public transport operators<sup>4</sup> and road planning and construction authorities. Thirdly, the information would form a basis for the comparison of alternative transport plans, and the choice of an optimal policy. For example, estimates for the costs and benefits derived from road construction and related works, could be compared with corresponding estimates for an improved public transport system.

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4. In the 1964 Transportation Study for Hobart, forecasts were made that the demand for public transport would increase by 47 per cent during the period 1964-1985. However the trend away from using public transport has continued, and since 1964 an 18 per cent decline in public transport demand has occurred.





Fig.1. Demand for Bus Public Transport - Hobart, 1955-56 to 1969-70.

Source: Annual Reports of the Metropolitan Transport Trust.

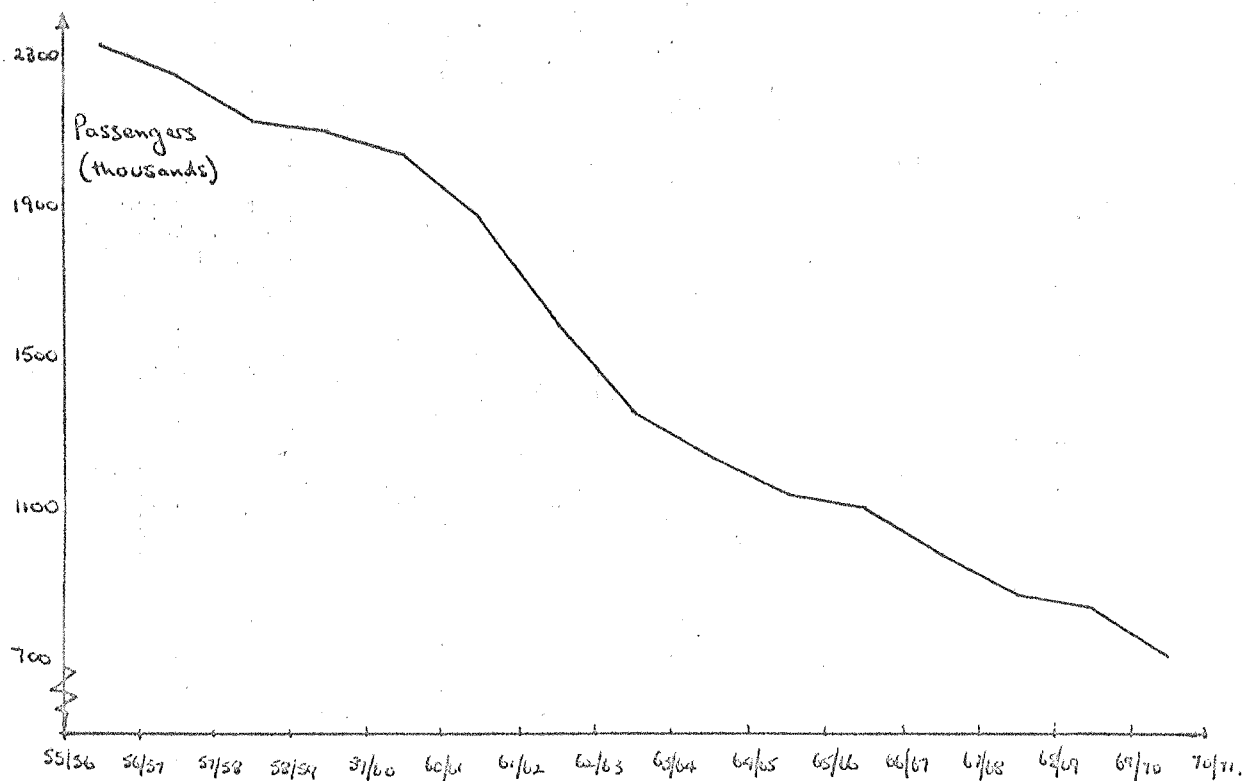


Fig.2. Demand for Rail Public Transport - Hobart, 1955-56 to 1969-70.

Source: Annual Reports of the Transport Commission.

## CHAPTER TWO

### TRAVEL DEMAND MODELS

This chapter contains a summary of, and the ideas embodied in three models of the demand for public transport which have been estimated using time series data. From a consideration of the validity of these ideas and their usefulness in explaining past demand, the model proposed in Chapter 3 was derived. A brief introduction to the study of travel demand is provided as a basis for the formulation of models considered in this and the following chapters.

Regional models of transport demand have been formulated and estimated using either time series or cross sectional data. Those based on cross section data are used to explain for various transport modes, the variation in travel demand which occurs between different traffic zones<sup>1</sup> in a region at a point in time. The explanations are made in terms of:

- (1) the characteristics of the transport modes,
- (2) the nature of the trip (whether the trip was for business purposes, or for social reasons, or home to work travel),
- (3) the geographic nature of the zone (for example, distance from, and ease of access to other zones) and

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1. A zone may be defined as that area the inhabitants of which exhibit similar characteristics for some classificatory variables usually of a socio-economic and geographic nature. The region under consideration therefore, consists of one or more of these zones.

- (4) either the characteristics of individual members of the zones<sup>2</sup> or the average characteristics of individuals within the zone.<sup>3</sup>

Models based on time series data employ aggregate travel data pertaining to a succession of time periods and are used to identify the factors contributing to the past travel demand patterns for each mode. Some of the travel characteristics are similar to those used for cross section models, but relate to different time periods (rather than between different zones). The demand models may relate to inter-zonal or intra-zonal travel. Although one comprehensive cross-sectional study of the travel demand for Hobart has already been completed<sup>4</sup> a second study was considered beyond the scope of this dissertation. It was therefore decided to consider in further detail only those models formulated for, and estimated with time series data.

#### Model 1

Characteristic of most of the time series models used in estimating the demand for inter-city travel by a single transport mode are those used by Brown and Watkins<sup>5</sup> for air passenger travel. Some of the models tried by Brown and Watkins can be represented by the following equations:

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2. For example, see S.L. Warner, Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice. (North Western University Press, 1962).
  3. For example, see Wilbur Smith and Associates, Hobart Area Transportation Study (Hobart, 1965). (Subsequently referred to as HATS), I, pp.89-105.
  4. *ibid.*, pp. 55-132.
  5. S. Brown and W. Watkins, "The Demand for Air Travel. A Regression Study of Time Series and Cross Sectional Data in the U.S. Domestic Market", Highway Research Record, No. 213, pp.21-34.

$$\log \text{RPM}_t = a_{10} + a_{11} \log F_t + a_{12} \log Y_t + a_{13} \log T \quad (1)$$

$$\log \Delta \text{RPM}_t = a_{20} + a_{21} \log \Delta F_t + a_{22} \log \Delta Y_t + a_{23} \log T \quad (2)$$

$$\log \text{RPM}_t = a_{30} + a_{31} \log F_t + a_{32} \log Y_t + a_{33} \log T + a_{34} \log \text{RPM}_{t-1} \quad (3)$$

where RPM = per capita passenger demand for inter-city travel in miles,

F = real average fare per mile,

Y = per capita real disposable income,

T = trend term in years.

These and similar equations were estimated by single equation least squares (SELS) using annual data for the period 1946 to 1966 inclusive.

The above models contain three distinctive features. Firstly, the form of the equations are such that the direct elasticities of demand are readily obtainable. However such relationships are based on the behavioural assumption that people react to relative changes in these variables irrespective of the values assumed by the variables in the relation.<sup>6</sup>

Secondly, the influence of population on demand was allowed for by using per capita demand as the dependent variable. An alternative, common in cross-section models, would have been to use the populations of the two cities as explanatory variables.

Thirdly, the lagged endogeneous variable in equation (3) was introduced to test the hypothesis that

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6. The explanatory variable may legitimately be included in log form if there is reason to believe that the effect of a change of this variable on the dependent variable, is inversely related to the level of the explanatory variable. This point is further discussed in S.J. Prais, and H.S. Houthakker, The Analysis of Family Budgets (Cambridge University Press, 1955) pp.82-88.

passenger demand was related to 'expected fares'<sup>7</sup> on the basis that the effects of changes in fares on air travel demand may be felt over more than one period. This is equivalent to an 'adaptive expectations' hypothesis similar to that proposed by Nerlove<sup>8</sup> to explain changes in the supply of agricultural products.

#### Limitations of the Models

Such single equation models suffer from four criticisms. Firstly they refer to travel only for one mode and contain characteristics of only that mode. As the private car may be a close substitute for public transport by bus, rail and air, the demand for, and the characteristics of these modes should be included where relevant.

Secondly, as the models are 'mode-specific' they provide neither forecasts of, nor the share of travel demand that the mode under consideration has attracted. The use of such models for forecasting implicitly implies that, given the same growth rates of income, population, and fares, the demand for intra city travel by air will continue to grow as rapidly in the future as it has in the past.

Thirdly, the time trend was introduced to act as a proxy for improvements in service and changes in tastes. It was found that the time trend did reduce the serial correlation in the residuals, but at the expense

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- 7. The 'expected fare' consisted of the sum of past fares, each weighted by a geometrically declining term.
  - 8. M. Nerlove, "Adaptive Expectations and the Cobweb Phenomena", Quarterly Journal of Economics, Vol. 72, pp. 227-240.

of introducing collinearity with the income variable. Thus the respective influences of the time trend and the income variable could not be separated. Similar problems were found by Lave<sup>9</sup> when a time trend was introduced in linear form.

Lastly, in a situation of unsatisfied demand any increases in the frequency of scheduled services would not only enable additional passengers to be transported by that mode, but also attract passengers to travel by that mode. Thus the inclusion of a service variable as exogenous may not be strictly valid on the grounds that the influence of this variable on demand may not be 'one way'.<sup>10</sup> Lave<sup>11</sup> identified two ways to overcome the problem of the interdependence between the modal characteristics and the demand for travel for each mode.

The first way is to formulate a system of equations, one for each mode, in which each equation incorporates the demand characteristics considered relevant for that mode, and to estimate the parameters of the equations of the model simultaneously. Thus tests of the existence, form and size of any interactions between the travel characteristics could be made. A model based on this principle is discussed below. (See model 3).

The second way is to include in the demand equation for some particular mode, certain characteristics

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9. L.B. Lave, "The Demand for Intercity Passenger Transportation", Journal of Regional Science, Vol. 12, No. 1, 1972. pp. 71-84.

10. For a discussion of the 'one way' rule, see A. J. Hagger, Price Stability, Growth and Balance, (Cheshire, 1968), pp. 34-36.

11. Lave, op. cit., p.75.

of the other modes which were thought to have had some influence on the demand for travel for the mode under consideration. This is the basis of the Quandt-Baumol Abstract Mode models,<sup>12</sup> which may be conveniently represented by the following equation:

$$RPM^i = a_{40} X^{a_{41}} F^{a_{42}} \left(\frac{F^i}{F}\right)^{a_{43}} S^{a_{44}} \left(\frac{S^i}{S}\right)^{a_{45}} D^{a_{46}} \left(\frac{D^i}{D}\right)^{a_{47}} \quad (4)$$

where  $RPM^i$  = number of revenue-passenger-miles carried by mode  $i$ ,

$F$  = fare for the journey under consideration by the cheapest mode,

$F^i$  = fare for the journey under consideration by mode  $i$ ,

$S$  = speed for the journey under consideration of the fastest mode,

$S^i$  = speed for the journey under consideration of mode  $i$ ,

$D$  = departure frequency for the journey under consideration of the mode with the shortest scheduled time between vehicle departures,

$D^i$  = departure frequency for the journey under consideration for mode  $i$ ,

$X$  = a number of other variables which may affect demand.

The characteristics of the mode under consideration are included in such a form so as to test the behavioural hypothesis that the prospective traveller makes his choice

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12. For example, see R. Quandt, ed., The Demand for Travel: Theory and Measurement (Heath Lexington, 1970), pp.83-100.

of mode after consideration of which mode is the fastest, the cheapest and the most convenient. A variation of this hypothesis is discussed in model 2, which now follows.

### Model 2

Lave<sup>13</sup> has criticized the plausibility of the behavioural hypothesis included in the Quandt-Baumol model of equation (4), on the basis that no one mode is likely to offer the speed of air travel, the cheapness of bus travel and the convenience of car travel. Instead, for each travel mode, Lave introduced the speed and fare characteristics as ratios of the respective characteristics associated with travel by one mode. A form in which the parameters of the model were estimated is as follows:

$$\begin{aligned} \text{RPM}_t^i = & a_{50} Y_t + a_{51} \text{SAS}_t + \text{Rel } S_t^i (a_{52}^R + a_{53}^B + a_{54}^A) + \\ & a_{55} \text{SAF}_t + \text{Rel } F_t^i (a_{56}^R + a_{57}^B + a_{58}^A) + a_{59} D_t^1 + \\ & a_{5,10} D_t^2 + a_{5,11} R + a_{5,12} B + a_{5,13} A \end{aligned} \quad (5)$$

where  $\text{RPM}_t^i$  = number of revenue-passenger-miles carried by mode  $i$ ,

$i$  = automobile, rail, air or bus,

$Y$  = disposable income per capita,

$\text{SAS}$  = scheduled air speed,

$R$  = dummy variable with value equal to one if  $i$  refers to rail, and has value zero if it does not,

$A$  = dummy variable with value equal to one if  $i$  refers to automobile, and has value zero if it does not,

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13. Lave, op. cit., p.72.



$B$  = dummy variable with value equal to one if  $i$  refers to bus, and has value of zero if it does not,

Rel  $S^i$  = speed of mode  $i$  relative to the scheduled air speed,

Rel  $F^i$  = fare via mode  $i$  relative to the fare by air,

$D^1$  = proportion of families with income between \$7,000 and \$10,000,

$D^2$  = proportion of families with income greater than \$10,000.

The parameters of the model were estimated by SELS using time series data for each mode, over the period 1945-66 inclusive. Variations of this model were formulated with all the variables included in log form. However the linear in variables relation was considered superior as the signs and magnitudes of the coefficients were found to be consistent a priori, than those obtained using the log-linear relationship. Further, the high degree of collinearity found to exist between the variables in each log-linear relation was reduced when the variables were specified in linear form. This however was found to result in significant serial correlation in the error terms.

One interesting feature of equation (5) is the introduction of some measure of the income distribution ( $D^1$  and  $D^2$ ), however no reasons for the choice of \$7,000 and \$10,000 as cut-off points were given.

Finally this model does not have the desirable property that a change in one of the characteristics of a mode (other than the base mode) should affect the demand for travel by the other modes. If this property were to

be incorporated in the model the characteristics of all the modes would need to be included in the demand relation instead of the base mode acting as a proxy for the other modes. However, for time series data, the collinearity problems are likely to frustrate such an approach.

### Model 3

Shepherd<sup>14</sup> formulated a comparative static multi-mode simultaneous equation model to facilitate both the analysis and the forecasting of intra-city demand for passenger travel. The structural form of the model may be represented in the following manner:

$$\begin{aligned} \log A_{it} = & a_{60} + a_{61} \log B_{it} + a_{62} \log D_{it} + a_{63} \log Q_{it} + \\ & a_{64} \log Y_{it} + a_{65} \log T_{it} + a_{66} \log H_{it} \end{aligned} \quad (6)$$

$$\begin{aligned} \log C_{it} = & a_{70} + a_{71} \log A_{it} + a_{72} \log D_{it} + a_{73} \log Q_{it} + \\ & a_{74} \log Y_{it} + a_{75} \log T_{it} + a_{76} \log R_{it} + \\ & a_{77} \log S_{it} \end{aligned} \quad (7)$$

$$\begin{aligned} \log D_{it} = & a_{80} + a_{81} \log A_{it} + a_{82} \log C_{it} + a_{83} \log Q_{it} + \\ & a_{84} \log Y_{it} + a_{85} \log T_{it} + a_{86} \log V_{it} + \\ & a_{87} \log W_{it} \end{aligned} \quad (8)$$

$$\log B_{it} = a_{90} + a_{91} \log C_{it} + a_{92} \log D_{it} \quad (9)$$

where the variables have the following interpretations:

### Variables

#### Endogeneous

#### Interpretation

$A_i$	per capita car ownership in city i,
$B_i$	per capita public transport journeys in city i = $C_i + D_i$ ,

14. L.S. Shepherd, "An Econometric Analysis of Car Ownership and Public Transport Use in Australian State Capital Cities", Paper presented to the Australasian Conference of Econometricians, August 1971.

EndogeneousInterpretation

$C_i$	per capita <u>road</u> public transport journeys in city i,
$D_i$	per capita <u>rail</u> public transport journeys in city i,

Exogeneous

$H_i$	amount of installment credit devoted to car purchase in city i,
$P_i$	index of new car purchase price for city i,
$Q_i$	index of car operating costs for city i,
$R_i$	road public transport route miles per 1,000 people, for city i,
$S_i$	road public transport vehicle miles per route mile for city i,
$V_i$	rail public transport route miles per 1,000 people for city i,
$W_i$	rail public transport vehicle miles per route mile for city i,
$T_i$	index of road and rail public transport fares for city i,
$Y_i$	per capita personal disposable income in city i.

The coefficients of the model were estimated by two stage least squares for each of the six Australian State Capital cities using time series data from 1955 to 1969 inclusive.

Consider now the hypotheses included in each of the equations (6) to (9). Equation (6) was designed to test the hypotheses that car ownership (A) depends on:

- (1) The demand for public transportation ( $B = C + D$ )  
or as Shepherd stated,

"...This assumes....that some car purchases are made to escape the disadvantage of public transport use."<sup>15</sup>

- (2) The level of consumer credit made available for car purchase (H)
- (3) The purchase price (P) and operating costs (Q) for a car, the public transport fares (T) and personal income (Y).

Equations (7) and (8) were postulated by Shepherd to test the two hypotheses, that

"...[the] demand for each public transport mode depends on car ownership - ..."<sup>16</sup>

and that bus and rail travel compete for a share of the total public transport demand.

Measures of the service provided by rail (V and W) and bus (R and S) were included to see if they were significant factors in determining rail and bus demand respectively.

Income (Y) was included as a proxy variable to explain the commuters' average implicit valuation of time and their preference for the faster mode. However an increase in income may have two conflicting effects on the demand for travel by public transport depending on an individual's (or household) level of income. On the one hand, for low income households the increase in income may allow members of the household to make additional trips by public transport.

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15. ibid., p.12

16. ibid., p.12

Alternatively, for medium to high income households public transport may be an inferior good. This is so because the desire for faster more comfortable and convenient transport available from car travel can be satisfied by the purchase of a first (or additional) car by members of a household.

Thus some income distribution term and/or some desire or taste variable could be included to provide a better basis for analysing the effect of income.

Equation (9) was used as a modal split relationship to isolate the relative effects of changes in the total public transport demand (B) from those of changes in the demand for each public transport mode. No causal explanations for changes in the demand for public transport were included. This relation could not be expected to remain valid if services for one of the public transport modes were to be significantly improved in the future. In a later article<sup>17</sup> Shepherd replaced equation (9) with the identity

$$B_{it} \equiv C_{it} + D_{it} \quad (10)$$

As Shepherd was unable to obtain time series data for private vehicle trips the influence of this variable on public transport demand and car demand could not be ascertained. Thus the model does not provide a complete modal-split of the total transport task between private and public transport modes.

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17. L.E. Shepherd, "An Econometric Approach to the Demand for Urban Passenger Travel", paper 913, presented at the 6th Conference of the Australian Road Research Board, 1972.

## CHAPTER THREE

### ANALYTICAL FRAMEWORK

Section A of this chapter contains a review of the services, fares and competition between those transport modes which have been available for passenger travel within Hobart since 1950. Such a review was considered necessary in order to derive in Section B, a plausible basis for the formulation of an appropriate demand equation for each travel mode, in a form suitable for econometric estimation.

#### A. Industry Structure

##### 1. Road Public Transport

The Metropolitan Transport Trust (subsequently referred to as the M.T.T.) has the duty,

"...to provide, or secure or promote the provision of, an efficient, adequate, and economical, and a properly integrated, system of public transport by road within the metropolitan areas."<sup>1</sup>

For the purposes of the Act the Hobart Metropolitan area includes that area within a seven mile radius of the G.P.O. at Hobart.<sup>2</sup> The Act therefore permits other intra-city road public transport services to collect passengers from within (outside) this area, provided that they are destined beyond (inside) this area. The M.T.T. were considered to have provided the only intra-city road public transport service since suitable data on transport services provided by private companies were not available.

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1. Metropolitan Transport Act, 1954, Section 12, subsection 2.

2. This 7 mile boundary includes most of the densely populated areas of the cities of Hobart and Glenorchy and the municipalities of Clarence and Kingborough.

Any errors incurred by this approximation were not considered to greatly affect the validity of the model as the M.T.T. does transport over 85 per cent of the total daily demand for road public transport passengers trips in the Urban Hobart Area.

Since 1969 the M.T.T. has used only petrol and deisel buses; trolley bus services were discontinued in 1968 and trams in 1960. For the purposes of this dissertation, these vehicles will be treated as having offered an homogeneous service, and will subsequently be referred to as buses.

A review of the nature of the competitive environment in which the M.T.T. has attempted to carry out its duty, will help to identify some factors partly responsible for the decline in bus demand. Since 1960, off-peak bus passenger travel has declined and as considerable spare capacity is available during these periods, a normal economic reaction would be to decrease the price (that is the fare). However, while required under the Act to operate an economical service, the M.T.T. are not free to engage in fare reductions or concessions, but rather the fares when altered, are usually adjusted in line with those applicable for the 'Standard States'.<sup>3</sup>

Conversely, total travel demand has increased rapidly, especially during peak hours, but as no road pricing scheme has been employed to ration the available road space, time (and hence congestion) has performed the rationing operation.

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3. Victoria and New South Wales.

This has been to the disadvantage of the M.T.T. as the buses are contained within the congested traffic flow, and their service potential cannot therefore be fully realized. Further, since most of the day-parking facilities in the city areas are free, many city commuters consider travel by bus to be more expensive (in terms of 'out of pocket costs') than an equivalent journey by car. In terms of travel time and frequency of service, bus travel is usually considered inferior to the use of a car. The effectiveness of the available capacity to satisfy the demand has been reduced by the increased city traffic congestion resulting in slower average bus speeds, while the increased decentralization of the population away from the city centres has necessitated the introduction of new services to these areas. Thus in the absence of additional buses, the number of peak hour services to any one area would decline. Since 1961, additional buses have only been purchased at a yearly rate of approximately 1.2 per cent, while service route mileage has increased at almost 2 per cent. Over the same period total travel demand has increased by approximately 8 per cent per annum.

This slow rate of addition to bus capacity may be due to the fact that bus demand has decreased and/or the belief that the purchase and operation of additional buses for more peak-hour services may not be economical.<sup>4</sup>

From discussions with officers of the M.T.T., it appears that the M.T.T. has tried to provide a service to

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4. W.J. Tyson, "The Problem in Road Passenger Transport: An Empirical Study", Journal of Transport Economics and Policy, Vol. 5 (January, 1972), pp. 77-84. (Tyson's conclusion was that for Manchester, additional revenues did not cover the cost of the supply of additional peak hour bus services.)



all sections of the community - including pensioners, low income earners and school children, as well as to engage in competition with private car users for a share of the peak hour travel demand. However, the unavailability of spare (bus) capacity in peak hours has reduced the ability of the M.T.T. to provide the service necessary to attract commuters away from car travel.

A recent study carried out by the P.M.D. revealed that over 90 per cent of M.T.T. passenger trips in Launceston were made by persons who, at the time the trips were made, did not have an alternative mode of transport available. (Such passengers are usually termed captives.) A similar situation may apply to Hobart bus commuters. Therefore, changes in the travel characteristics of other modes, *ceteris paribus*, are unlikely to have a significant effect on the demand for travel on M.T.T. services. However the converse may not apply, in that high fares, uncomfortable seats and slow infrequent services may no longer be acceptable to some persons previously captive. For such people the purchase and use of a car may offer the only alternative.

## 2. Rail Public Transport

Suburban Rail services in Hobart are controlled by the Transport Commission. These services operate along the main double track Hobart to Launceston railway line, passing through 18 suburban stations as far north as Brighton. In addition services are routed along the branch-line to Risdon. The last daily rail census in 1970 shows that a total of 50 week-day services were operated and attracted a daily average of 2,300 passengers, 65 per cent

of whom travelled during the hours of 7.00 - 8.30 a.m. and 4.00 - 5.30 p.m.<sup>5</sup> From discussions with officers of the Transport Commission it was ascertained that the patronage of suburban rail services has (since 1955) declined during the peak and off-peak periods by approximately the same percentage amount. Also, since 1955 considerable reductions both in terms of the number of scheduled train journeys per day and the number of rail carriages hauled per train journey, have been made.

In contrast to bus passengers, rail passengers generally have at least one choice of an alternative travel mode (i.e. by bus) and often two (by bus or by car). Thus the demand for train travel may be more sensitive to changes in the characteristics of other travel modes than is the demand for bus travel. Generally, adult fares for an equivalent distance travelled have been approximately 60 per cent cheaper by train than by bus.

### 3. Passenger Ferry Service

From 1945 to 1963, the Transport Commission operated a passenger ferry service from the Hobart waterfront to Rosny and Bellerive on the Eastern shore. The need for such a service was reduced due to improvements of bus services to the Eastern shore and the replacement in 1964 of the 'floating bridge' with a 4-lane 'Arch' bridge of considerably increased capacity. Insufficient patronage contributed to the decision to abandon the service.

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5. Unpublished data, made available by an officer of the Transport Commission.

Ferry fares were charged according to the status of the passenger (adult, child) irrespective of the trip destination. These fares were approximately equal to the fare charged for a 4 section bus trip from Bellerive to Hobart. The attractiveness of ferry travel was partially increased while feeder bus services to Bellerive from Howrah were operated; however the introduction of 'through' services from Howrah to Hobart in 1954 offset this advantage. The attractiveness of ferry services was further reduced in 1957 when the number of weekday ferry return trips was decreased from 22 to 12. No information was available on the distribution of demand during an average weekday.

#### B. Formulation of the Model

In this section, demand functions are derived for travel by each public transport mode, total travel and car ownership. Basically, the relationships obtained from traditional consumer demand theory, have been modified by taking ideas from various studies on travel demand and where considered appropriate, certain other hypotheses were included.

##### 1. Road Public Transport Demand

One feature of equation (7) is the explicit inclusion of car ownership (A) and rail demand (D) as explanatory variables. However in Hobart at least, the effect of the competition between rail and bus services on bus demand may not be significant, as suitable and adequate rail services are available to only a small proportion of the population. Thus, rail services and rail demand were not included as explanatory variables for bus demand.

The introduction of television has been associated by both Webb<sup>6</sup> and the M.T.T.<sup>7</sup> with the decline in public transport patronage during the 7.00 p.m. to 11.30 p.m. period in Melbourne and Hobart respectively. Further, two Hobart cinema-theatre managers believed that a decline in theatre audiences of approximately 50 per cent occurring during the years 1962 to 1964, was due mainly to television being used as an alternative means of entertainment. As many theatre patrons also use public transport, an hypothesis worth testing is that television (denoted by TV ) has been one factor causing a decline in bus transport usage.

This would not be the only factor causing the decline, as the number of passengers carried by the M.T.T. had started to decrease in 1958. On the other hand, car registrations have shown a steady increase in Tasmania and as car travel may be the only practical alternative mode of travel for many bus commuters, the increased availability of cars may have had a causal effect on public transport demand. The variable car registrations, was used as a proxy for 'car availability', in the demand function (and denoted by A). However, the availability of parking in city areas has decreased, whilst its cost has increased. Since traffic congestion has also increased, advantages of car usage especially during the peak periods are diminished in relation to public transport usage. Thus the marginal effect of car ownership on bus demand may not

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6. G.R. Webb, "Urban Transport - The Emerging Problem", Australian Economic Papers, Vol. 2, June 1963, p.78.

7. Metropolitan Transport Trust, Report and Statement of Accounts, 1962/63 and 1963/64.

be constant, but inversely proportional to the level of car ownership. To test this hypothesis, car registrations were included as an explanatory variable, in a log form.

Since many bus passengers are captive and the purchase of a car is an expensive alternative, some time may be required for individuals to be able to change from bus to car travel. Hence any adjustment of bus demand to changes in bus fares may take longer than one period to 'work itself out'. In such a case, a 'partial adjustment' model may provide an approximate form of the dynamic behaviour.<sup>8</sup> Bus demand lagged one period will therefore be included as an explanatory variable.

To investigate the effect of changes in income on bus demand, two alternative measures of income were used, namely real disposable income per capita, and real disposable income per employed person.

Lave found that the two income distribution variables ( $D^1$  and  $D^2$ ) in equation (5), although not always significant in alternative demand functions, at least  $D^1$  did have a negative coefficient in most cases tried. The implication of this result is that public transport may be an inferior good for those persons who earnt an income above a certain level. Such a result seems plausible and this hypothesis was included in the demand equations for bus and rail travel. Only one income distribution variable, defined as the proportion

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8. Under this hypothesis, bus demand for a given period is adjusted according to the discrepancy between the desired level of demand during that period and the level of demand in the previous period. For a mathematical derivation of this model, see H. Theil, Principles of Econometrics, (North Holland, 1971), pp. 258-262.

of all income earners whose income was less than the state basic wage was used and was denoted by  $YD_1$ .

Rather than a variable for new car prices as used by Shepherd, a measure of the annual cost ( $P$ ) that a car owner would incur was included in the bus demand function. This cost included depreciation, registration and insurance. Operating costs such as petrol, oil and tyres were not included in the demand function as data were not available. It may well be that these operating costs are not considered by a commuter when choosing his mode of travel, especially if a car is available.

Finally, three variables were included which represent measures of the quantity (denoted by  $BQ$ ) accessibility ( $BA$ ) and convenience ( $BC$ ) of bus services provided in the Urban Hobart area. The level of each variable has been available for manipulation by the bus public transport authorities. One form of the bus demand function for the Urban Hobart area, incorporating the variables considered relevant from the above discussion is:

$$C_t = b_{10} + b_{11}TV_t + b_{12}T_t^b + b_{13}\log A_t + b_{14}P_t + b_{15}Y_t + b_{16}YD_{1t} + b_{17}BA_t + b_{18}BQ_t + b_{19}BC_t + b_{1,10}C_{t-1} + u_{1t} \quad (11)$$

where  $C$  = per capita demand for bus public transport,

$TV$  = per capita level of television ownership,

$T^b$  = bus public transport fare in 1967/68 prices,

$A$  = per capita level of car ownership,

$P$  = annual cost of owning a car in 1967/68 prices,

$Y$  = personal disposable income in 1967/68 prices,

$YD_1$  = proportion of those income earners, who  
earnt less than the state basic wage,

BA = route miles of bus services per capita, as  
 a proxy for the accessibility of services,  
 BQ = vehicle miles of bus services per capita,  
 as a proxy for the quantity of bus services,  
 BC = route miles per bus, as a proxy for the  
 convenience of bus services.

## 2. Rail Public Transport Demand

As rail public transport demand has declined in a similar manner (although more rapidly), to that shown by bus public transport and the causal factors are probably similar, some of those variables considered relevant for an explanation of bus demand may also be useful in explaining the demand for rail travel. However some variations in the form of this demand function were made. Since the decline in the demand for rail services has not been confined to off-peak periods, television may not be an appropriate causal factor. Rather, it is believed that the increased availability of cars, more competition from buses, and fewer scheduled rail services<sup>9</sup> have been the main factors responsible for the decline in rail demand.

The quantity, accessibility, convenience and fares associated with rail travel will be included as ratios of the equivalent measures for bus travel. Such a formulation is similar to that used in model 2 but with buses acting as the 'base mode'. Relative speeds were not used as the data was not available; however the actual differences are probably small, at least for comparisons between bus and rail travel. Lagged rail demand was

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9. See supra p. 20

also included as an explanatory variable to test for the presence of a 'partial adjustment' form of dynamic behaviour for rail demand.

A form of the demand function containing those variables considered relevant is:

$$D_t = b_{20} + b_{21} \frac{T_t^R}{T_t} + b_{22} A_t + b_{23} P_t + b_{24} Y_t + b_{25} YD_{2t} + b_{26} RA_t + b_{27} RQ_t + b_{28} RC_t + b_{29} RV_t + b_{2,10} RB_t + b_{2,11} D_{t-1} + u_{2t} \quad (12)$$

where  $D$  = per capita demand for suburban rail public transport,

$T^R$  = rail fare in 1967/68 prices,

$A$  = per capita level of car ownership,

$P$  = annual cost of owning a car in 1967/68 prices,

$Y$  = personal disposable income in 1967/68 prices,

$YD_2$  = proportion of male income earners who earnt less than the state basic wage,

$RA$  = rail route miles per capita as a proxy for the accessibility of rail services,

$RQ$  = rail vehicle miles per capita, as a proxy for the quantity of rail services,

$RC$  = ratio of rail route miles with bus route miles,

$RV$  = ratio of rail vehicle miles with bus vehicle miles,

$RB$  = ratio of rail fares with bus fares, for an equivalent journey.



### 3. Car Ownership

Ironmonger and Kumar<sup>10</sup> suggested the use of the level of unemployment as a proxy variable for the effect of credit conditions on car demand. This variable avoids the criticism made against the use of the installment credit devoted to car purchase (H) as used by Shepherd in equation (6), because the level of unemployment in Hobart is not likely to be significantly affected by changes in car demand in the same period. Lagged levels of unemployment and current and lagged differences between the level of unemployment and registered vacancies were also used. Two new hypotheses were formulated and included in the demand function.

The first hypothesis was that changes in the 'desires' for car ownership have occurred and influenced car demand. To test this hypothesis a proxy variable (NCD) equal to the rate of change of new car demand was used. The second hypothesis included was that for a given period, car demand is a function of the number of trips that an individual expects to make during that period. The expected number of person-trips<sup>11</sup> was assumed equal to the actual number of person-trips made in the same period.

Other variables considered relevant, include bus fares, car costs, income and income distribution, and were included in the car demand function. One possible form of the car demand function, embodying those variables considered relevant is:

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10. D.S. Ironmonger, and S. Kumar, "Econometric Models of the Australian Economy." Paper presented to the Conference of Australian Economists, Melbourne, 1970.

11. The number of person-trips was defined as the

$$A_t = b_{30} + b_{31}A_{t-1} + b_{32}NCD_t + b_{33}PT_t + b_{34}U_t + b_{35}Y_t + b_{36}YD_{1t} + b_{37}T_t^b + b_{38}P_t + b_{39}BA_t + u_{3t} \quad (13)$$

where NCD = a proxy for 'desires', equal to the rate of change of new car demand,

PT = per capita number of person-trips made by persons using private and public transport,

U = level of unemployment.

#### 4. Passenger Ferry Demand

Since travel by car and bus were the main alternative transport modes for Bellerive ferry passengers changes in the cost and availability of travel by these modes may have influenced the demand for ferry travel. Similarly to equation (12), fares and 'service' were included as ratios of the corresponding variables associated with bus travel, as this was the main public transport alternative available to ferry passengers. However the only ferry supply variable which changed during the period 1950-62, was the number of trips per day (denoted by FS).

One equation in which an hypothesis of inter modal competition was tested is:

$$F_t = b_{40} + b_{41}T_t^f + b_{42}\frac{T_t^f}{T_t^B} + b_{43}FS_t + b_{44}\frac{FS_t}{BR_t} + b_{45}F_{t-1} + b_{46}Y_t + b_{47}YD_{1t} + b_{48}BO_t + u_{4t} \quad (14)$$

where F = per capita demand for the Bellerive ferry services,

$T_t^f$  = one way ferry fare,

$T_t^B$  = 4 section bus fare,

FS = number of daily ferry services,

BR = bus route miles.

Thus the model for public transport demand consists of equations (11) to (14). Before this model can be estimated it must be 'complete' in that the number of endogeneous variables must equal the number of equations in the model. From Hagger,<sup>12</sup> a variable may be treated as predetermined provided that this variable can only influence (and not be influenced by) the level of the variable to be explained. Using this criterion,  $TV$ ,  $T^b$ ,  $P$ ,  $Y$ ,  $YD_1$ ,  $YD_2$ ,  $T^r$ ,  $RB$ ,  $U$ ,  $T^B$ ,  $D_{-1}$ ,  $C_{-1}$ ,  $A_{-1}$  can be treated as predetermined. The treatment of services supplied by rail ( $RA$ ,  $RQ$ ,  $RC$ ,  $RV$ ), ferry ( $FS$ ), and bus ( $BR$ ,  $BA$ ,  $BQ$ ,  $BC$ ) as predetermined may not be strictly correct if the level of these variables were adjusted in the same period in response to changes in demand. However, these services are under the control of transport authorities and changes in their level are generally made only after a consideration of many other factors. As a first approximation, these service variables were treated as predetermined.

This leaves 5 variables  $PT$ ,  $C$ ,  $D$ ,  $A$ ,  $F$ , as currently endogeneous but the model is not complete as it contains only 4 equations. An equation to explain the per capita demand for intra-city travel ( $PT$ ) was obtained using the relationship:

$$PT_t = \left(\frac{PV}{PO}\right)_t + C_t + D_t + F_t \quad (15)$$

where  $PV$  = total number of person trips made by car,  
 $PO$  = population.

For reasons discussed in Chapter 4, (infra pp. 38-40)  $PV$  was treated as predetermined.

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12. A.J. Hagger, Price Stability, Growth and Balance, (Cheshire, 1968) pp. 34-36.

AVAILABILITY AND ASSESSMENT OF STATISTICAL INFORMATION

The methods used to construct time series data for each of the variables that appear in the model to be estimated, are described below. This data is then assessed as to its accuracy, adequacy of coverage and finally the consequent effect on the validity of any conclusions which may be drawn from the estimation of the model.

1. Bus Passenger Trips

Annual data for the number of passengers carried by the M.T.T. in Hobart since 1955/56, are published in Metropolitan Transport Trust: Report and Statement of Accounts (subsequently referred to as the M.T.T. reports). As stated earlier (supra p. 16) the M.T.T. was considered to have operated the only bus service in the Hobart area. The data are believed accurate, but do not include those passengers who would have used bus transport if sufficient bus capacity had been made available. It was not possible to ascertain the extent of such unsatisfied demand.

2. Bus Service Variable

Annual figures for the number of vehicle miles, vehicle route miles, and vehicles operated by the M.T.T., have been published in the M.T.T. reports for Hobart since 1955/56. These figures may not provide an adequate explanation for the changes in supply for four reasons.

Firstly, they have not been adjusted for school children trips. Thus the figures for vehicle miles and the number of buses, overestimate the scheduled supply made available for use by the Urban Hobart population.

The second reason is that the Urban Hobart statistical boundary is not equivalent to the boundary within which the M.T.T. has operated. The area from Claremont to Granton, although included in the Urban Statistical Area, has not been serviced by the M.T.T. Thirdly such factors as operating speeds, comfort and reliability of services, the 'convenience' of the vehicle routes to work and residence locations may all have some effect on an individual's choice of travel mode. However no time series data were available for these factors. The final reason is that the actual number of buses at any one time is less than the number theoretically available. During peak hours, approximately 90 per cent of the M.T.T. buses are in fact used, the remainder are required for spares or repairs.

### 3. Bus Fares

Two measures of bus fares were employed using data contained in the M.T.T. reports. The first measure was equal to the fare charged for an 'average' journey of 6 sections (approximately 6 miles), as at the end of each financial year, for an adult passenger. The second measure used was the fare for the first section as at the end of each financial year, for an adult passenger.

These were both considered unsatisfactory as changes in fares have occurred during the financial years, rather than at the start, and so the measures used do not show the actual fares operative throughout each year. Also, according to an officer of the M.T.T., the length of an average trip made by an adult has been slowly increasing since 1955. Another factor which must be considered to affect the usefulness of the data is that bus fares for

*Measurement of  
average price  
changes?*

school children are considerably less than the adult fare. Since school children trips have increased both in relation to adult trips and in absolute numbers, the use of adult fares may seriously overestimate the 'average' fare paid by bus travellers.

#### 4. Rail Passenger Journeys

Annual figures for suburban rail passenger trips are published in The Transport Commission Report (subsequently referred to as the T.C.R.) for the years 1955/56 to 1970/71 inclusive.

The annual figures can, with one qualification, be expected to represent the actual level of demand for those areas in which the service was provided. The qualification is that 'workers weekly tickets' issued by the Transport Commission allow the holder to make an unlimited number of journeys between stations nominated on the ticket when issued. In the compilation of the figures for passenger journeys, holders of such tickets were assumed to have made 10 trips during the week of issue of the ticket.

#### 5. Rail Service Variables

Annual figures for suburban steam and diesel locomotive miles and rail car miles operated for the suburban service are published in the T.C.R. The route mileage has remained constant at 18 (miles). The figures for vehicle miles may not be accurate for two reasons. Firstly, their collection required the drivers to record in log books the vehicle miles travelled by suburban services separate from those relating to the intra-state service. For various reasons this may not be done, and it was not possible to estimate the extent of any such discrepancies.

which have arisen. Secondly, steam and diesel locomotives have, in general been reserved for operation during peak hours, and they usually haul more than one passenger carriage. No information on the number of 'passenger-carriage-miles' pulled by these locomotives was available. Further, rail-cars<sup>1</sup> may join in pairs (or more) with either one or both rail-car engines running; but the mileage figures relate only to the actual number of miles the engines were operated. Thus the aggregation of these two sets of figures for locomotive and rail-car mileages is unlikely to provide an accurate measure of the supply of rail services.

#### 6. Rail Fares

No published figures for rail fares for the period 1955 to 1970 were available. However with the help of an officer of the Transport Commission it was possible to obtain most, if not all, the past fare schedules from unpublished sources.

The system for charging rail fares has changed three times since 1955. To retain comparability of the data for rail fares, it was decided to use the adult fare for a six mile train journey. This may not be representative of the fares paid by regular rail users as they would tend to use the 'workers weekly' tickets, or a book of 10 tickets which may be purchased for concession rates. As a large percentage of suburban train users are probably regular users, it could be expected that they would take advantage of these concession fares. Also, from figures published

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1. A rail-car consists of a diesel engine and a conjoined passenger carriage.

in the T.C.R., the length of the average suburban rail trip has increased over the period 1955/56 to 1969/70 from 5.3 to 6.9 miles.

#### 7. Ferry Passenger Demand

Annual figures for passengers carried on scheduled Bellerive ferry trips, were published in the T.C.R. until, and including, the year 1961/62. These figures were taken as accurate, and no adjustments were made. As the ferry service was discontinued in June 1963, the period of the analysis is not consistent with that used for the other public transport modes. To gain additional observations on this variable, the period of analysis was extended back to include 1951/52 for the ferry demand equation.

#### 8. Ferry Service

Unpublished information for the number of scheduled weekday return journeys provided by the Bellerive ferry service was obtained from Officers of the Transport Commission. Also, it was ascertained that other ferry service variables (return-trip times, and ferry capacity<sup>2</sup>) had not altered over the period 1951/52 to 1961/62. The introduction of a feeder bus service from Howrah to Bellerive for ferry passengers, may have increased the 'attractiveness' of travel by ferry for Howrah residents.

#### 9. Ferry Fares

Information on ferry fares for scheduled trips from 1952/53, was provided by officers of the Transport

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2. The capacities of the two alternative vessels available, were the same (596 persons).



Commission. Unlike bus and train fares, ferry fares did not vary according to the distance travelled, but were charged according to the status of the passenger (adult or child).

#### 10. Population

Census and annual inter-censal estimates for the state and Urban Hobart population, are contained in the CBCS publications Population of Local Government Areas and Principal Urban Centres in Tasmania, for the period 30th June 1966 to 30th June 1971 inclusive. Population estimates for the municipalities of Clarence and Kingborough, and the cities of Glenorchy and Hobart are contained in earlier publications of the same bulletin. Estimates for the number of persons in the Kingborough Municipality who resided within the Urban Hobart area<sup>3</sup> (if such a classification had been in operation) were made from the population estimates for this municipality for the years prior to 1966. Similarly, estimates for the number of persons who resided within the urban areas of Glenorchy and Hobart were also made.<sup>4</sup>

#### 11. Car Registrations

Annual figures for Tasmanian car and station wagon registrations as at 30th June for each year (or the registrations received within one month after that date)

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3. This classification was introduced in 1966. For a description of the Urban Hobart Area and how it differs from the Hobart and Suburbs Area and the Hobart Metropolitan Area, see Tasmania Year Book (Hobart: Government Printer), Vol. 2, 1968, pp.131-133.

4. The ratio of urban to rural residents in these city areas was obtained from the Census and inter censal estimates for 1966 to 1971. The trends in these ratios were extrapolated back to 1955.

are published in the T.C.R. Additional data for car ownership levels in the Hobart and Suburbs area, were obtained from the 1955 and 1962 Census of Motor Vehicles published by the Commonwealth Statistician. Additional information for car ownership by Local Government Areas for the years 1965 to 1970 (excluding 1968) was provided by an officer of the Transport Commission.

Annual figures for new car registrations since 1955 in the Hobart Metropolitan Area, are published in the Annual Bulletin of Motor Vehicle Registrations, by the Commonwealth Statistician.

The calculations used to obtain the annual figures for the car registrations in the Urban Hobart area, are contained in Appendix A. Basically the data were adjusted so that they referred to the same period. For the years prior to 1965, the level of car registrations in year  $t$  were obtained from the corresponding level of car registrations in year  $t-1$ , plus new car registrations in year  $t$ , less the number of vehicles deregistered during year  $t$ .

Even after these calculations, the data were not considered to represent accurately the actual demand for cars. This is so because the stock of cars, held by second-hand dealers has not been accounted for. Also, vehicles are registered by the Transport Commission according to the address of the registered owner. Vehicles owned by State and Semi-Government departments are usually registered in Hobart, even if the vehicles are for use in other areas of the state. This over estimation for car demand caused by these two factors, may be partially compensated by the omission of motor cycles, panel vans

and utilities from the figures for car ownership. Also the difficulty and delays associated with the transhipment of cars to Tasmania prior to 1962 may have resulted in some new car demand being unsatisfied.

## 12. Income

Annual figures for the disposable income of Tasmanian taxpayers are published by the CBCS in Commonwealth Tax Assessments (CTA). Per capita disposable income was obtained by dividing total disposable income by the estimated state population. These figures were deflated by the Consumer Price Index (CPI) to obtain real personal disposable income. Real disposable income per taxpayer was obtained in a similar manner.

## 13. Income Distribution

Annual data for the state basic wage level are published in Statistics of the State of Tasmania, by the CBCS, while figures for the number of taxpayers who earned a taxable income within certain income ranges, are published in CTA. An appropriate pro-rata adjustment was made when the annual state basic wage did not coincide with the income ranges used in CTA. The use of average state income measures to represent the income for Urban Hobart residents may not give an adequate indication of their income, and the effect of income as an explanatory variable may be biased.

## 13. Television

Annual figures for the number of television and television combined with radio licence fees paid by residents of the Hobart Metropolitan Statistical Division are published in Transport and Communication by the CBCS

for the years ended 30th June 1959 to 1970. Pro-rata population estimates were used to derive the number of television licences held by residents within the Urban Hobart area. These figures however do not necessarily represent the level of television ownership, as one licence allows a person or organization to own and operate any number of television sets within one dwelling (as with hotels and motels).

#### 14. Unemployment

Monthly statistics of the level of persons registered as unemployed and registered vacancies are published in the Monthly Review of the Employment Situation by the Department of Labour and National Service. Annual figures were obtained from these monthly figures. However, as they relate to the Hobart District Office Area<sup>5</sup> the registered unemployed and vacancies for the Urban Hobart Area were determined by multiplying the annual figures by an appropriate population factor obtained from population census data.

#### 15. Vehicle Trips

Unpublished data for vehicle counts for several streets and highways in various parts of the Urban Hobart area were made available by officers of the Public Works Department (PWD), the Hobart City Council (HCC) and the Transport Commission. This information was not considered suitable for use in the model for the following reasons.

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5. This area includes 19 municipalities and may approximately be defined as that area south of an East-West line through the town of Oatlands, excluding the municipalities of Queenstown, Zeehan and Strahan.

Firstly, the vehicle counts indicate neither the number of vehicle trips nor the number of person trips made during the period of the traffic count. Only two estimates of the number of daily vehicle trips within the Urban Hobart area, were available.<sup>6</sup> Secondly, the vehicle counts included all vehicles, not just cars, that crossed over the vehicle counter. Thirdly, some of the 'counts' were made for 12 hour periods, others for 24 hour periods; also some 'counts' were adjusted for the day of the week they were taken, others were not adjusted. Considerable monthly variations also occur, and so the counts would not necessarily be representative of the situation during each year.

Further no annual figures were available for daily traffic counts on any street in Hobart for the period 1955 to 1970 inclusive. The best data available was for the Brooker Highway - however no vehicle counts were made between 1964 and 1967 inclusive, nor in 1958 and 1961. Also, this route carries a great deal of inter-city traffic, and hence travel growth along this route would not be representative of the intra-city travel growth pattern. In view of these problems, it was decided to use a constant growth rate of 10 per cent per annum<sup>7</sup> for the daily number of person trips by car. The corresponding 1964 figure, contained in the HATS report<sup>8</sup> was used as an origin, from

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6. The first is published in the HATS Report (p.153) and pertained to an 'average' day in 1964, the second was obtained from an officer of the PWD, and pertained to an 'average' day in 1970.
  7. This growth rate was obtained from a weighted average of the growth rates shown by the vehicle counts for those streets and highways in Hobart, for which vehicle count data was available in consecutive years.
  8. See footnote 6.

which the figures for all other years between 1955 and 1970 were obtained. The figure 'predicted' by this method for 1970, was found to agree closely with that obtained by the P.W.D.

#### 16. Car Costs

Information on new and used car prices and car operating costs were not readily available. Further, these costs could be expected to differ greatly between the different brands and models of cars available. It was therefore decided to use one measure of the 'average' annual cost of owning a car. Annual figures for the licence, vehicle registration, 'Third Party' and Comprehensive insurance costs were made available by a representative of the Fire and Accident Underwriters of Tasmania. These figures were supplemented where necessary, by published data in the R.T.C. and Walches' Almanac for the period 1952/53 to 1970/71 inclusive. To these actual costs, a measure of the 'average depreciation' on an 'average car' was added. The method used to derive this 'cost' is contained in Appendix B.

The non inclusion of a variable for car operating costs and parking costs may not be important when the model is used for explanatory purposes. However, when the model was used for forecasting demand by each travel mode, the exclusion of these costs reduced its predictive power.

#### 17. Time Period

The statistics for the level of Television ownership for Hobart and state measures for disposable income

and the income distribution were available only for the years prior to 1969/70. Also, as no data for route and vehicle miles of buses, and bus fares for years prior to 1955<sup>9</sup> were available, the period of the analysis for bus, train and car travel was reduced to the 15 year period 1955/56 to 1969/70 inclusive. For the ferry demand function, data for the period 1952/53 to 1961/62 was available, and used.

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9. The H.C.C. operated the bus and tram services in Hobart prior to the acquisition of these services by the MTT in 1955.

## CHAPTER FIVE

### EXAMINATION OF THE PROBLEM

In this chapter, results from the estimation of the model as formulated in Chapter 3 will be reviewed in the light of the data limitations discussed in Chapter 4. Firstly however, the estimation problems encountered will be discussed, followed by the procedures used to reduce their effects, and evaluate each regression.

#### A. Estimation Problems

##### 1. Multicollinearity

Multicollinearity is said to occur when one or more approximate (or exact) linear relations exist between some of the explanatory variables in an equation.<sup>1</sup> The existence of such auxiliary relationships may decrease the precision with which the estimated coefficients can be stated,<sup>2</sup> cause the estimates of the coefficients to be biased, and make the separation of the respective influences of the linearly related variables very difficult if not impossible. Conversely, as Christ has shown,<sup>3</sup> the exclusion of a causal variable from a relation may result in biased estimates for the coefficient of those variables included in the relation. (This is termed specification bias.) However, one of the main functions of the model is to predict future travel demand so that the exclusion of some of the collinear variables may not be too serious, provided that the correlations between included and

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1. If a linear relation exists between only 2 explanatory variables, the term collinear will be used.
  2. When the auxiliary relation is an exact relation, then the coefficients of the model and their standard errors, cannot be obtained.
  3. C.F. Christ, Econometric Models and Methods, (Wiley, 1965), p.387.



excluded variables are expected to continue in the future.

## 2. Serial Correlation of the Residuals

One of the basic assumptions of the Classical Model is that successive disturbance terms ( $u_i$ ) are independent of all previous values.

$$\text{i.e. } E[u_i u_j] = \begin{cases} 0 & \text{if } i \neq j \\ \sigma_u^2 & \text{if } i = j \end{cases}$$

This assumption may be violated if auto-correlation in the data of one or more explanatory variables are present, or if some of the variables which move in phase with each other rather than cancelling themselves out, have been omitted from the relationship estimated. In such circumstances SELS estimation may result in serious under-estimation of the sample variance and also inefficient sampling variances. Further, the use of the standard formulae for the calculation of the 't' and 'F' tests is invalid.<sup>4</sup>

The presence of first-order serial correlation of the residuals may be detected by the use of the Durbin-Watson Statistic (DWS) when the explanatory variables are strictly exogeneous. The use of the DWS may not be strictly correct when lagged endogeneous variables are included,<sup>5</sup> or if the model consists of a system of simultaneous equations. However, the selection of the upper boundary ( $du$ ) for the critical region may to some extent, compensate for errors resulting from the use of the DWS in multi-equation models.

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4. For a fuller discussion of these problems, see J. Johnson, Econometric Methods (McGraw-Hill, 1963), p.179.

5. In such circumstances, the DWS is biased towards the value 2 - which is the value the statistic would have if no positive or negative serial correlation was present in the residuals.

In recommending this procedure, Christ has said,

"If it errs somewhat, it will be by giving false signals of serial correlation slightly too often when no such correlation exists."<sup>6</sup>

### 3. Estimation Method

The parameters of the structural equations (11) to (14) were estimated using SELS. The effect of the inclusion in some of these equations of currently endogenous variables as explanatory variables, is discussed below.

The structural equations (11), (12), (13), (15) can be represented in the form:

$$Bx + Cy + \eta = 0 \quad (16)$$

where  $x = (4 \times 1)$  vector of the currently endogeneous variables,

$B = (4 \times 4)$  matrix of coefficients =  $|b_{ij}|$  for  $i, j = 1, 2, 3, 4$ .

$y = (n \times 1)$  vector of predetermined variables,

$C = (n \times n)$  matrix of coefficients,

$\eta = (4 \times 1)$  vector of disturbances,

$n =$  number of predetermined variables in the model.

Estimation of these equations in (16) by SELS will result in biased estimates for the coefficients of  $C$ , unless the restriction that the explanatory variables be either non-stochastic or independently distributed is satisfied. In addition, unless the structural equations are 'recursive', then the estimates will not have the desirable property of

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6. Christ, op. cit., p.528.

consistency.<sup>7</sup> Malinvaud has defined a recursive system as one where

"...there exists an ordering of the endogenous variables ( $i = 1, 2, \dots, n$ ) such that the matrix  $B$  is triangular and the covariance matrix of  $\eta$  is diagonal, that is, if

$$b_{ij} = 0 \text{ for all } j > i$$

$$E[\eta_{it}\eta_{jt}] = 0 \text{ for all } j \neq i."$$
<sup>8</sup>

An examination of equations (11), (12), (13), (15) reveals that the model does not satisfy the first of these two restrictions. The second restriction,

$$E[\eta_{it}\eta_{jt}] = 0 \text{ for all } j \neq i$$

may also not hold as the same, unidentified, factors which have affected the demand for bus travel may have also affected the demand for train travel.

While simultaneous equation methods of estimation may help to reduce the bias and eliminate the inconsistency, the considerable computational requirements of such estimation procedures precluded their usage in the initial stages. However, it was possible to perform a two stage least squares computation for the 'best' relations found from the SELS estimation method, which facilitated a comparison of the coefficients of the variables obtained by these two methods.

Although some loss of the postulated simultaneous nature of the model has resulted from using SELS, this procedure did allow the testing of a wide range of hypotheses. Further some of the cross elasticities between modes could

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7. Inconsistency of the parameter estimate is caused by a non zero correlation of the disturbance term and the explanatory endogenous variable(s).

8. E. Malinvaud, Statistical Methods of Econometrics, (North Holland, 1970), p.612.

still be obtained as each demand equation contained at least some of the characteristics of the mode of the main competitor(s).

#### 4. Regression Evaluation Procedure

For each relation estimated by SELS, the hypothesis that the residuals show no first order serial correlation was tested against the alternative hypothesis that the residuals were positively correlated.<sup>9</sup> The 5 per cent level of significance was used for the calculation of the critical region.

The result was said to be 'unfavourable' when the D'S fell within the intermediate or critical regions, which indicated that the presence of positive serial correlation could not be 'discounted' at the 5 per cent level of significance. In such circumstances, an additional variable was introduced into the relation if it was expected to help reduce the serial correlation.

Where the D'S was favourable, 't' and 'F' tests were applied. The 't' ratio<sup>10</sup> was used to test the hypothesis that the regression coefficient of an explanatory variable was equal to zero at the 5 per cent level of significance, against the alternative hypothesis that it was different from zero. The 'F' test was used to test the hypothesis that all the coefficients of the explanatory variables in a relation were equal to zero against the

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9. When the relations were estimated in first difference form, the alternative hypothesis of negative serial correlation was used.

10. The test statistic used was equal to the ratio of the coefficient of the variable and its standard error.

hypothesis that they were different from zero.<sup>11</sup> The 0.1 per cent level of significance was used, unless otherwise stated.

Since it is possible to increase  $R^2$  by increasing the number of regressors, the statistic  $\bar{R}^2 = 1 - \frac{T-1}{T-K-1} (1-R^2)$  was used for choosing among functions with different numbers of regressors.

As multicollinearity between the data for the explanatory variables was a severe problem in the estimation of the coefficients, the following procedure was adopted to recognize and reduce its effect. Firstly, each of the dependent variables was regressed with one explanatory variable. Generally the DWS was 'unfavourable', and so the second stage was carried out. To each of the explanatory variables considered satisfactory on the basis of the t - test and with correct sign a priori, one additional variable (say  $X_2$ ) was added,<sup>12</sup> and for this new equation the coefficients and statistics DWS,  $\bar{R}^2$  were estimated. Provided that each of the following conditions were met  $X_2$  was accepted as an additional explanatory variable.

- (1) the DWS was favourable,
- (2)  $\bar{R}^2$  was increased,
- (3) the standard error of the first variable was not greatly increased in relation to its coefficient, such that the coefficient became highly insignificant,

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11. For such a test, the test statistic used was

$$F(K, T-K-1) = \frac{R^2/K}{(1-R^2)/(T-K-1)}$$

where  $R^2$  is the coefficient of determination,  $K$  is the number of explanatory variables and  $T$  is the number of observations on the dependent variable.

12.  $X_2$  was selected if its inclusion with the other explanatory variables was considered reasonable a priori.

- (4) the coefficient of  $X_2$  was plausible a priori, and was significant.

If  $X_2$  was accepted, an additional explanatory variable was added, and the procedure repeated.

## B. Estimation Results

The results from the estimation of equations (11) to (14) by SELS are discussed below. However three results were found which applied to all regressions estimated. Firstly, the log-linear relationships gave inferior results compared with those obtained from linear relationships on the basis of the DWS, F-test and t-ratios. Secondly, the use of first differences of the linear relations did not provide a satisfactory explanation of demand. The variables were seldom significant and  $\bar{R}^2$  always less than 0.5. Finally, the lagged dependent variable, although significant, was found to be multicollinear with most of the other explanatory variables. Hence it was not possible to make any definite conclusions on the form of the dynamic adjustment hypothesized in Chapter 3.

### 1. Bus Demand

The outstanding result obtained from 140 regressions for bus demand was the consistent performance of the television variable (TV). It was significant in each relation in which it was included and was seldom collinear with other variables. Car ownership (A) was also usually significant - however it was found to be collinear with bus fares ( $T^b$ ), income (Y) and income distribution ( $YD_1$ ). Although the inclusion of A in log form did help to

improve  $\bar{R}^2$ , it was not included in this form for the relation when estimated by two stage least squares. Surprisingly, car costs (P) were found not to be significant in any of the regressions in which this variable was included. However, the limitations of the data should be considered in assessing this result. Real bus fares, both for one and six sections were found to be significant with correct sign a priori.<sup>13</sup>

The three proxy variables for bus service (BA, BC and BQ) were seldom significant with correct sign. This may indicate that other supply characteristics may be more important determinants of modal choice - for example travel time.

Two results were obtained that indicated bus services may be an inferior good. The first result was that income (Y) was usually significant with a negative sign, (although it was multicollinear with TV and A) while the second result was that income distribution ( $YD_1$ ) was also significant with a positive sign.<sup>14</sup>

The best fitting relationship with a favourable DWS and minimum multicollinearity was considered to be:

$$C_t = 444 - 48.6\log A_t - 0.19TV_t \quad (17)$$

(7.0) (-3.9)                      (-6.4)

$$\bar{R}^2 = 0.983 \quad F = 194 \quad SEE^{15} = 3.82 \quad DWS = 2.61$$

The figures in brackets refer to the t-ratios for the respective coefficients. The high coefficient found for

13. However the six section fare was found to be multicollinear with A and TV. From a regression for these variables with fares as endogeneous,  $\bar{R}^2$  was found to be 0.94. The use of a dummy variable taking the value 1 when fares were increased and 0 otherwise was found not to give significantly better  $\bar{R}^2$ , although the problem of multicollinearity was reduced.

14. For the regression of C with  $YD_1$  as the only explanatory variable,  $\bar{R}^2$  was 0.90, the DWS was favourable, and the t-ratio was 11.4.

15. Standard error of the estimate C.

the constant term, may provide some indication of the extent of captive passengers, for example, school children.

## 2. Rail Demand

In contrast to bus demand, rail demand appeared to be considerably affected by the level of rail services provided, and from competition with bus services. The coefficients of these variables must be viewed with some suspicion when considered in the light of the accuracy of the data for train vehicle miles (as used in RV).

Rail fares either as real, actual or as a ratio with bus fares usually had a positive coefficient, (which was not expected) but were seldom significant. It would therefore appear that fares have not greatly affected rail demand.

As with bus demand, A was found to be significant although it was collinear with Y and  $YD_2$ . Also Y and  $YD_2$  were usually significant with negative and positive coefficients respectively, but were multicollinear with RV and RC.

From the results obtained from 84 regressions for rail demand, the best fitting relation was:

$$D_t = 14.25 - 0.035A_t + 318.2RV_t - 33.6RC_t \quad (18)$$

(6.8)    (-5.0)        (9.6)        (-5.5)

$$\bar{R}^2 = 0.990 \quad F = 270 \quad SEE = 0.633 \quad DWS = 2.17$$

## 3. Car Demand

The variable  $YD_1$  was found to be highly significant and stable for those car demand functions in which it was included. As expected, the sign of the coefficient was negative, in contrast to the positive coefficient found for rail and bus demand. Income (Y) was generally significant with a positive coefficient, however the coefficient did



decrease when the variable PT was added.

The coefficient for total personal trips (PT) was also found to be highly significant, stable and correct sign a priori. However considering the assumptions contained in the formulation of this variable, the actual size and level of significance of the coefficient may be questionable.

The real car price variable (P) was not significant in any of the relationships estimated. It was felt that a division of the new and second hand car prices, or a 'car-price distribution' variable<sup>16</sup> may provide a better representation of the effects of car 'prices', but data was not available in a form suitable for its inclusion.

The level of unemployment (U), which acted as a proxy for the credit conditions was found to be generally unsatisfactory. Although not appreciably collinear with other variables, the coefficient was quite unstable. For similar reasons  $U_{-1}$  was found to be unsatisfactory.

The best relationship for explaining the demand for cars, was considered to be:

$$A_t = 59.86 + 0.211PT_t + 0.095Y_t - 306YD_{-1} \quad (19)$$

(1.62)      (5.69)      (1.72)      (-3.34)

$$\bar{R}^2 = 0.991 \quad F = 285 \quad SEE = 5.22 \quad DWS = 1.80$$

#### 4. Ferry Demand

The income distribution variable ( $YD_{-1}$ ) was again found to be quite significant with a stable positive coefficient in each demand equation tested, indicating a

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16. For example, the proportion of cars with market value above \$2,000.

similar behavioural reaction as was obtained from the regressions with bus and rail demand. However, income (Y) was not significant in any of the relations estimated.

Ferry fares ( $T^f$ ) were collinear with A, however the inclusion of  $T^f$  as a ratio with bus fares ( $T^B$ ) did reduce both the collinearity problems and the serial correlation in the residuals.

The variable BQ was quite significant with a negative coefficient, but was found to be collinear with A, and therefore did not allow the separation of the effect of these two variables on ferry demand.

From the regressions on ferry demand, the best relation was considered to be:

$$F = 46.67 - 18.8 \frac{T^f}{T^B} - 170A_t \quad (20)$$

$$(13.9) \quad (-4.9) \quad (-10.8)$$

$$\bar{R}^2 = 0.953 \quad F = 36 \quad SEE = 0.876 \quad DWS = 3.14.$$

The 'F' values were noticeably lower than those found for the other 3 demand relationships - this may partially be due to the small number (9) of annual observations available.

#### 4. Estimation by Two Stage Least Squares

As data for ferry demand was not available for the years 1962/63 to 1969/70, equation (20) was excluded from the system of equations to be estimated by the two stage least squares (TSLS) procedure.<sup>17</sup> Therefore, the variable F had to be excluded from equation (15), and this equation was reduced to:

$$PT_t = \left(\frac{PV}{PO}\right)_t + C_t + D_t \quad (21)$$

17. For an outline of the two stage least squares estimation procedure and its properties, see Johnson, *op. cit.*, pp. 258-260, 275-295. Goldberger, A.S., *Econometric Methods* (Wiley, 1964), pp. 329-336.

It was possible to estimate by TOLS only one of the many possible alternative forms of the structural equations of the model. As equations (17) and (18) were considered to best represent the demand for bus and rail travel, and equation (19) for car demand, it was decided to use these and (21) to form the model to be estimated by TOLS.

The results obtained by this method were in close agreement with those found by SELS. However the standard errors were generally reduced, the coefficients of the predetermined variables were slightly increased, and the  $\bar{R}^2$  were increased, but only marginally. It was therefore considered that the other results found for each demand equation when estimated by SELS would probably also closely approximate those results obtained when estimated as part of a simultaneous equation model.

### C. Forecasts from the Model

In order to be able to make predictions with a simultaneous equation model, it is necessary to derive the reduced form.<sup>18</sup> This can be obtained either by solving the set of simultaneous structural equations<sup>19</sup> or by SELS estimation of the relationships expressing each endogenous variable as a function of only predetermined variables. The latter method was used and the results obtained are given below:

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18. The reduced <sup>form</sup> consists of a set of equations where each currently endogenous variable is expressed in terms of predetermined variables only.

19. For example, the solution of equation (16) for the endogenous variables is given by  $x = -B^{-1}Cy - B^{-1}v$

$$\begin{aligned}
 A_t &= 108 - 168.1YD_{1t} + .056Y_t - .048TV_t - 496RV_t + 81.8RC_t + .216PV_t \\
 PT_t &= 284 - 86.6YD_{1t} + .099Y_t - .231TV_t + 318RV_t - 19.6RC_t + .993PV_t \\
 C_t &= 227 - 3.84YD_{1t} - .040Y_t - .190TV_t + 200RV_t - 35.1RC_t - .029PV_t \\
 D_t &= 11.5 + 6.05YD_{1t} + .004Y_t - .016TV_t + 226RV_t - 22.7RC_t - .009PV_t
 \end{aligned}$$

The performance of the model in explaining past demand, may be investigated by inserting the observed values for each predetermined variable, in each of the reduced form equations. This was done for bus and rail demand for the years 1955/56 to 1969/70, and the results are presented in Table 1.

TABLE 1

Per Capita Bus Demand			Per Capita Rail Demand		
Estimated	Actual	% error	Estimated	Actual	% error
193.3	193.0	-0.16	24.51	24.60	0.36
192.8	193.2	0.19	22.85	22.71	-0.67
1957-58 196.0	201.4	2.63	20.93	21.14	0.36
194.0	189.2	-2.53	20.30	20.00	-1.53
183.9	185.0	0.62	18.81	19.11	1.54
165.4	165.9	0.03	16.22	16.87	4.05
160.9	156.7	-2.65	14.91	14.03	-6.50
153.1	152.0	-0.67	11.47	11.68	2.00
146.9	148.9	1.35	10.55	10.51	-0.43
138.2	142.3	2.90	9.65	9.63	-0.24
137.2	133.1	-3.06	9.41	9.18	-2.48
128.6	129.4	1.41	8.20	8.05	1.85
126.6	124.6	-1.64	6.96	7.04	1.14
118.2	120.4	1.79	6.22	6.71	7.30
115.6	115.4	-1.27	5.82	5.59	-4.06

One important feature of these results, is that the model was able to 'predict' the per capita increase in bus travel which occurred in 1957/58, and its decline in the succeeding year. The limitations of the data for rail

vehicle miles (one component of RV) and the omission of rail fares as an explanatory variable may be responsible for some of the errors of the models' predictions for rail demand.

The model was used to make forecasts of the demand for bus and rail travel, for those years subsequent to 1969/70, by inserting values for each of the predetermined variables,<sup>20</sup> in the relevant reduced form equation. Thus, forecasts for 1970/71, and 1971/72 per capita travel demand by bus and rail were made and compared with the actual demand for these years.

TABLE 2

Per Capita Bus Demand			Per Capita Rail Demand	
	Forecast	Actual	Forecast	Actual
1970/71	111.4	114.0	5.17	4.90
1971/72	107.0	106.0 <sup>21</sup>	4.18	4.52 <sup>21</sup>

The results are contained in Table 2. In addition forecasts of the demand for bus and rail services in 1974/75 were made on the assumption that no major policy changes in public transport would occur. This 'no change' policy was called policy A. Forecasts were also made for the level of bus and rail demand resulting from a 50 per cent increase in bus vehicle miles over the period 1969/70 to 1974/75

20. In the model under consideration, all predetermined variables are exogeneous (i.e. their actual values are determined by factors external to the model). On the assumption that past trends in these exogenous variables would continue, their post 1969/70 values were obtained by extrapolation of the trends in these variables over the past ten years, unless the actual data was available for that year.

21. The actual per capita demand figures for 1971/72 are approximate only, as no Urban Hobart population estimates were available for that year.

(policy B) and from a policy of restraining the demand for private vehicle trips to the 1969/70 level (policy C). Finally, policy D was formulated as a combination of policies B and C. The results are presented in Table 3.

TABLE 3

Per Capita Bus Demand			Per Capita Rail Demand	
1974/75	Forecast	Effect	Forecast	Effect
Policy A	94.0	n.r.	1.70	n.r.
Policy B	94.6	+0.6	1.00	-0.70
Policy C	102.5	+8.5	4.27	+2.57
Policy D	103.1	+9.1	3.57	+1.87
n.r. - not relevant				

Thus it may be seen that bus demand is not very responsive to increases in bus vehicle miles, and that private vehicle users are unlikely to change to using bus and rail transport, even if they are restricted from using their cars for some journeys.

It must be noted that these forecasts are made under quite restrictive assumptions which may not, in practice, be valid. For example, it was assumed that no changes in any of the implicit relationships which existed during the estimation period between the variables included in and those excluded from the model would occur during the forecast period. Further, it was assumed that those variables included in the model will continue to affect the demand for each mode in a similar manner in the future.

SUMMARY

In Chapter 1, the need was noted for a possible alternative to the high community cost and capital outlays associated with the construction of intra Urban Hobart road access facilities. As provision of increased and better public transport services may be the only alternative, it was considered important that the likely effect on demand be known for such changes in public transport services.

A model to explain the demand for each travel mode was developed in Chapter 3 and the results obtained from the estimation of the model were discussed in Chapter 5. It was found that personal income, bus fares, television and car ownership were significant factors affecting bus demand, while competition from buses and the level of car ownership were the main factors affecting rail demand. The high values for both  $\bar{R}^2$  and the significance of the variables in the final equations, indicated that most of the past changes in travel demand were adequately explained by this model.

Forecasts were made for the likely future effects on bus and rail demand of three policy measures which could possibly be implemented to increase the demand for public transportation. The results obtained indicated that no one policy may be adequate and that unless several policies are implemented to increase the attractiveness of public transport, even at the expense of private vehicle usage, then public transport is unlikely to be able to reduce the need for improved city access and car parking facilities.

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A. Construction of the Data for Car Ownership

Data for the level of car ownership in the Urban Hobart Area was obtained using the following procedure.

Firstly, for the years 1964/65 to 1969/70 inclusive, data was obtained from the Transport Commission for the level of car ownership in each Local Government Area (LGA). However the boundaries of the relevant LGA's do not coincide with the Urban Hobart Area boundary. Therefore, population estimates for each LGA were used to reduce the level of car ownership within that LGA to a per capita basis. These per capita figures were then multiplied by the estimated Urban Hobart population residing within the respective LGA. The sum of these products was used as the estimated level of car ownership in the Urban Hobart Area for the years 1964/65 to 1969/70 inclusive.

Secondly, the published data for the 1955 and 1962 CBCS Census of Motor vehicles, were used for both years. However two adjustments had to be made. The first was necessary because the Census figures pertained to the 30th December of these years, rather than the 30th June. This adjustment was made according to the following formula:

$$A_{t+1}^J = A_t^D + \frac{1}{2} \text{NCR}_{t+1} - \frac{1}{2} \text{SCDR}_t \cdot A_t^J \quad (1)$$

where  $A^J$  = Car ownership in the Hobart and Suburbs area,  
as at 30th June,

$A^D$  = Car ownership in the Hobart and Suburbs area,  
as at 30th December,

NCR = new car registrations in the Hobart and Suburbs area,

SCDR = Car deregistration rate for Tasmania.<sup>1</sup>

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1. See equation (3) below for the derivation of this variable.

The second adjustment to the Census figures was necessary because they related to the Hobart and Suburbs area, rather than the Urban Hobart Area. Therefore, population estimates for the Hobart and Suburbs Area were used to deflate the adjusted Census figures, and these per capita figures were multiplied by the estimated Urban Hobart population for the appropriate years.

Thirdly, for the intercensal years prior to 1964/65, the following procedure was adopted:

$$CUHR_t = CUHR_{t-1} + NCRUH_t - SCSR_t \cdot CUHR_{t-1} \quad (2)$$

where  $CUHR$  = cars on Urban Hobart 'Register',

$NCRUH$  = new cars registered in the Urban Hobart Area

$SCDR$  = car deregistration rate for Tasmania.

The state car deregistration rate was calculated by the following formula

$$SCDR_t = \frac{SCR_{t-1} + NCRT_t - SCR_t}{SCR_{t-1}} \quad (3)$$

where  $SCR$  = total car registrations in Tasmania

$NCRT$  = new car registrations in Tasmania.

#### B. Construction of the Data for Car Price

One of the implicit costs associated with car ownership is due to the depreciation of the car. While the rate of depreciation may vary depending on the age, model, mileage and type of car owned as well as the demand for second-hand cars, it was considered that a rate of 15% per annum would represent an 'average rate' of car depreciation

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2. This rate of 15% was obtained from discussions with second-hand car dealers and from information contained in a vehicle 'dealers guide' book.

Annual data for Tasmanian car values (in real terms) were obtained from figures determined by Burke,<sup>3</sup> for the years 1952 to 1969 inclusive. These figures were inflated by the Tasmanian Consumer Price Index to obtain actual car values, and 15% of these values was considered to be the appropriate depreciation cost for an average car.

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3. Burke, R.H., Atkins, A.S., and Coote, G.M., "Procedure for Forecasting Vehicle Miles of Travel in National Road Planning", Paper presented to the 6th Conference of the Australian Road Research Board, Melbourne, 1972